

## 5. SOIL MOISTURE PROBE

### 5.1 Introduction

Applied Research Associates, Inc. (ARA) developed the capacitance-based soil moisture sensor and web-based data acquisition and control system that are part of the monitoring system installed at RWMC. This system was selected because it contains the following features:

- Direct contact of the sensor with the soil
- Use of higher frequency oscillation (150 MHz) in the capacitance-measuring circuit
- Combination of three sensors (moisture, resistivity, and temperature) in a single package that can be pushed into the soil
- Data-handling and data-processing capabilities.

Although Vertek markets the probe for ARA as a standard off-the-shelf item for obtaining real-time, in situ logs of SMR, in some respects, the probe is still in the development stage. For example, in 2003 ARA redesigned the SMR probe and renamed it the “SMRT” probe. The SMR probe is designed with electrode rings circling the tip (see Figure 5-1) for measuring SMR. The two inner rings (second and fourth) determine the soil moisture content by measuring the frequency shift of a high-frequency excitation signal as it passes through the soil near the probe. Resistivity is measured by the two outer rings (first and fifth). Soil temperature is measured by the center ring (third).

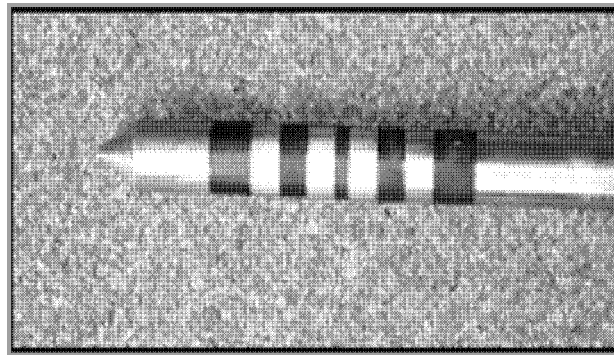


Figure 5-1. View showing the tip of the soil moisture, resistivity, and temperature probe with its electrode rings.

Seventy-eight of the SMR probes were pushed into soil and waste at RWMC in 2001. Target depths were at the top of the waste, near the bottom of the waste, and in sediment below the waste. The objective was to monitor infiltration that moved through the waste. Forty-eight of the 78 probes were functioning at least part of the time during FY 2003. Data collection from the probes is automated such that data are remotely collected at 2-hour intervals. Data are then transmitted from the dataloggers to a computer and placed in a shared file. From there, the data are pulled into an Excel spreadsheet for analysis. Data are collected as processed, meaning that calibration and other equations are applied to the data as they are collected.

## **5.2 Probe Calibration**

The SMR probes were calibrated using moisture extremes by taking readings in air and water. Once installed, the probes cannot be recalibrated without pulling them out of the soil, which is not possible when the probes are installed in or through waste. Because the probes were not calibrated to the actual soil conditions, the reported moisture contents should be viewed as relative rather than absolute values. In addition, metal objects located near the probes can affect the measured moisture content. Soil temperature, resistivity, and pore-water salinity also can impact the moisture content.

## **5.3 Fiscal Year 2003 Radioactive Waste Management Complex Precipitation**

Precipitation is important when considering potential infiltration. Although there are exceptions, low precipitation usually means low infiltration. At RWMC, the spring snowmelt has been shown to be the most significant infiltration event. The National Oceanic and Atmospheric Administration maintains precipitation records for the RWMC (NOAA 2004). On average, National Oceanic and Atmospheric Administration long-term records indicate that the INEEL receives 8.65 in. of precipitation annually (Clawson, Start, and Ricks 1989). The 2003 total precipitation at RWMC is less than half the average—4.28 in. (see Figure 1-3). The greatest monthly amount of precipitation occurred in April—just shy of 1.6 in. The maximum daily precipitation was 0.45 in. on April 28, 2003.

## **5.4 Summary of Soil Moisture and Soil Temperature Data Trends**

Plots of the soil moisture and temperature data for the functioning SMR probes are shown in Appendix C. Trends in the moisture and temperature are discussed below and presented in Table 5-1 (for 2003) and in Appendix C. Table 5-1 presents all of the 78 probes that were installed and categorizes their functionality (e.g., usable, questionable, or nonfunctioning).

## **5.5 Moisture Data**

Functioning SMR probes are installed in the subsurface at depths ranging from 1.67 to 19.86 ft. With the scant 2003 precipitation, infiltrating moisture at most sites should prove to be insignificant. However, heterogeneities in RWMC surficial soil promote preferential flow. Run-off water is known to collect in ditches along the roadways. These areas, at the expense of other flatter areas from which the water runs off, can receive substantial recharge even in years of drought. This means that if a SMR probe is located near a collection area and installed deep in the subsurface, it could indicate recharge while a shallow probe located in another area might not.

The SMR probes indicate that infiltration has occurred by showing an increasing moisture content that is reflected in a rising moisture trend. However, a slowly rising trend over a long period also could indicate that the probe may be impacted by other parameters (e.g., resistivity or salinity as well as temperature). A continued rising trend generally would not be expected as an indicator of recharge at RWMC. Rather, a rising trend and then a falling off a couple of weeks or months later is generally what has been observed in past moisture monitoring at RWMC. The fall-off would be the desired response to drying associated with decreased moisture following the moisture pulse. With long-term rising trends (for more than 1 year), resistivity readings might help to determine if infiltration is actually occurring as a result of a slowly moving wetting front, but at this point, the resistivity measurements are of no help. Another approach is to corroborate results with other moisture data (e.g., the tensiometer data). If the tensiometer data support the SMR data, it is a fairly safe conclusion that infiltration has occurred. Data

from any of the instruments are always stronger when they are corroborated by data from other independent measurements.

The SMR and tensiometer data indicate that infiltration has occurred at the MM1-2 cluster and perhaps at the PIT5-4 and PIT5-TW1 clusters. This is not surprising since Cluster MM1-2 is located near the haul road where water is known to pond. PIT5-4 and PIT5-TW1 also are located in areas where past observations indicate water ponds. Although we believe infiltration has occurred at these sites, the current quality of the SMR moisture data (e.g., temperature influences and calibration difficulties) does not allow a quantitative estimation of the amount of infiltration that has occurred.

Data plots for each of the functioning SMR probes (described below) with the trend discussion superimposed on the plots are shown in Appendix C. These are organized by borehole and probe depth.

The following provides a discussion of each of the SMR probes (and clusters), including long-term moisture trends (see Appendix C and Table 5-1):

- Cluster 741-08—Data appear to show a slightly rising trend in each of the three probes at this location (741-08-266, 741-08-267, and 741-08-268). However, two of the three trends are impacted by temperature. Probes 267 (4.4 ft bls) and 266 (19.86 ft bls) appear to be inversely correlated with the temperature measurements (see page C-3—Cluster 741-08—in Appendix C). These probes are located above the waste, in the waste, and near the bottom of the waste. Probe 268 (11.5 ft bls) indicates very low moisture, which could be reasonable given that this probe is located within the waste. If infiltration occurred at this location, it occurred between March and July and was slight. Since that time, the trend is flat.
- Cluster 743-03—Probe 743-03-235, installed at 3.36 ft bls, is significantly impacted by temperature. Even so, it appears to have a slightly rising trend over the long term as does its companion probe (743-03-237) that is installed deeper at this location. It is possible that a slight amount of infiltration occurred in this location, although it would be more convincing if the trends remained after removal of the temperature effect.
- Cluster 743-08—Data from Probes 743-08-247, 743-08-250, and 743-08-251 look similar to Cluster 743-03. Final trend on each probe seems to be slightly up, suggesting infiltration could have occurred, but again, the trends would be more convincing if they remained after removal of the temperature effect.
- Cluster 743-18—The trend for Probe 743-18-217 seems to be slightly up and then down, but the trend is cyclic and has the temperature influencing it; probably the true trend (after temperature influence is removed) is flat, indicating little or no infiltration has occurred at this location.
- Cluster MM1-2—Probe MM1-2-238 (6 ft bls) measurements indicate that infiltration has likely occurred in 2002 and 2003 at this location. The 2002 infiltration is supported by nearby tensiometer data.

- Cluster MM2-1—Probes MM 2-1-221, MM 2-1-231, and MM 2-1-241 are all potentially influenced by temperature. Their location is near the ditch by the haul road where water most likely ponded. Probe MM 2-1-221 seems to have a steady slightly rising trend but nothing corresponding to infiltration. However, perhaps Probe MM 2-1-241 and very likely Probe MM 2-1-231 have rising responses indicating possible infiltration in the March-April timeframe. Cluster MM2-2—Probes MM2-2-220 and MM2-2-222 (SMR probes) do not indicate that significant infiltration occurred at their locations, although it is possible that infiltration has occurred in the February-March timeframe at the 10.78-ft-bls (Probe MM2-2-224) location. However, data from this probe are noisy, but the recharge event seems to rise above the general noise in the data.
- Cluster MM2-3—Probe MM2-3-246 shows a jump around the middle of July. One might be tempted to believe the jump is in response to infiltration from a summer rainstorm because it jumps up rapidly and then falls off gradually. The problem with this assumption is that July precipitation data do not support such a storm. So, it is likely that something else, other than increased moisture content of the soil, is causing the jump, possibly instrument servicing. Neither of the other probes at this location (Probes MM2-3-215 and MM2-3-229) indicates infiltration.
- Cluster MM3-1—2002 tensiometer data indicate infiltration at 10.5 ft, and 2002 SMR Probe 242 (9.69 ft bls) data may indicate infiltration. Probe MM3-1-242 (at 9.69 ft) does not appear to show infiltration occurring in 2003. Temperature effects impact all probes at this location. If these effects were removed, infiltration might be more evident.
- Cluster MM3-2—Probes MM3-2-210 and MM3-2-216 are obviously impacted by temperature. The middle probe, Probe MM3-2-252, data are fairly flat.
- Cluster MM3-3—All probes at this location appear to have some degree of temperature effect. There does not appear to have been any infiltration at this location.
- Cluster PIT5-4—There is, perhaps, some infiltration at the 2.81-ft (Probe PIT5-4-289) and the 10.16-ft levels (Probe PIT5-4-285). To verify infiltration, the temperature effect needs to be removed. Probe PIT5-4-279 does not appear to indicate significant infiltration.
- Cluster PIT5-TW1—Temperature impacts all three probes at this location. The deeper two probes (Probes PIT5-TW1-282 and PIT5-TW1-291) appear to have rising trends, which might indicate infiltration. The shallow probe (Probe PIT5-TW1-290) may be indicating slight infiltration in February 2003.
- Cluster SVR-20—Little 2003 data. Cluster has only recently come back online. There is insufficient data to assess potential 2003 infiltration.
- The rest of the locations and probes have insufficient data to determine the potential of infiltration in their specific locations.

Table 5-1. Summary of soil moisture, resistivity, and temperature probes, depth, materials, temperature, and soil moisture.

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
741-08	267	4.40	Useful	Soil cover above waste	19.565 (8/21)	3.6739 (3/8)	22.427 (5/14)	15.4090 (9/1)	Moisture content seems to be inversely correlated to temperature. If moisture data can be believed (without removing temperature influences), the moisture content seems to be drying, which is consistent with Radioactive Waste Management Complex norms for this time of year.	The long-term trend is cyclic—upward as temperature trends down. Without removing the temperature component of the moisture data, it would be hard to predict the actual trend.
	268	11.50	Useful	Waste	16.086 (9/30)	9.0089 (4/17)	2.720 (7/26)	1.0977 (1/1)	No temperature dependence. Data are reasonable. Low-moisture content is consistent with dry waste with large void spaces. No significant moisture changes in waste near probe. Moisture minimum and maximum achieved on several dates.	Over time, slight upward trend, which could indicate some infiltration.
	266	19.86	Useful	Bottom of waste	12.815 (9/29)	9.5864 (6/19)	23.701 (5/3)	21.5080 (1/1)	Temperature and moisture seem to be slightly inversely correlated. Does not appear to be any real moisture changes near probe during quarter. Jump in temperature on 8/28 may reflect field servicing.	Basically flat for the last part of 2003. A flat trend suggests that the moisture conditions are not changing. Over time, though, the trend is slightly cyclic and appears to be increasing. Need to remove temperature effects from data.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
743-03	235	3.36	Useful	Soil cover above waste	20.614 (8/25)	4.8863 (3/11)	35.432 (8/22)	25.7810 (8/22)	Temperature reflects probe's nearness to surface. Definite inverse correlation to temperature. Differences in moisture content would suggest that there was a wetting front passing the probe between 8/22 and 10/2. If the data are real, infiltration has occurred.	Cyclic. Current trend is up, but because of inverse correlation to temperature, trend cannot be trusted. Probably the true trend is flat or rising slightly, which would suggest that little or no infiltration is occurring.
	226	12.31	Nonfunctioning							
	237	19.09	Useful	Soil below waste	27.302 (1/1)	13.6040 (6/11)	62.141 (5/8)	25.7810 (8/22)	Differences in moisture content would suggest that there was a wetting front passing the probe between 8/22 and 10/2. If the data are real, infiltration has occurred. That the high temperature occurred in January suggests that there may be some problem with the temperature data.	Long-term trend appears to be rising slightly. Servicing of probe in early August resulted in dramatic drop in moisture values, which are probably more accurate. Trend continues gradual upward movement.
743-08	247	6.60	Useful	Soil cover above waste	22.449 (9/11)	21.0760 (9/30)	20.261 (9/28)	18.7600 (8/13)	First data 8/12. Doesn't appear to be influenced by temperature.	Trend is upward after sudden drop in moisture content (caused by servicing) in previous quarter.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	250	13.90	Useful	Waste	21.361 (9/29)	21.3060 (9/28)	14.538 (9/28)	14.4260 (9/30)	Not enough fourth-quarter data to analyze.	Not enough recent data to tell about fourth-quarter trends. Over the long term, though, there is a definite temperature influence on data. Although long-term trend is cyclic, the true trend appears to be rising, which suggests wetting may be occurring.
	251	22.28	Useful	Bottom of waste	N/A	N/A	N/A	N/A	Data from 9/10. Not enough data to give conclusions. Data appear to be influenced by temperature.	Trend appears to be up but not enough data to be sure. Trend also appears to have a temperature component, which must be removed.
743-18	217	6.47	Useful	Top of waste	20.028 (9/09)	18.6990 (9/30)	19.457 (9/13)	18.8610 (8/18)	The moisture data are influenced by temperature, which needs to be removed before the moisture data can be trusted. If the moisture data can be trusted, then infiltration could have occurred between 8/18 and 9/13. The minimum and maximum occur on more than one date; the dates given are representative.	The trend seems to be slightly up and then down, but the trend is cyclic and has the temperature influencing it so that it is hard to comment much about the actual moisture patterns. Probably the true trend is fairly flat, which would indicate little or no infiltration has occurred at this location.
	248	12.83	Nonfunctioning							
	236	19.2	Nonfunctioning							

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
MM1-1	232	5.5	Nonfunctioning							
	227	11.58	Questionable							
	211	18.7	Questionable							
MM1-2	238	6.00	Useful	Soil	21.376 (8/21)	1.9718 (3/10)	18.582 (6/22)	16.9392 (3/10)	Data to 9/10 only. Moisture maximum occurred on June 22, which is about the time that it is expected to be highest. This is an indicator that infiltration occurred at this location. The minimum temperature and moisture content occurring on the same day probably results from the temperature influence.	The long-term trend is somewhat cyclic but does not appear to be influenced by temperature and is possibly responding to actual moisture changes in the soil suggesting that infiltration is occurring. Fourth quarter trend is slightly down then slightly up.
	214	10.75	Nonfunctioning							
	219	13.89	Questionable							
MM1-3	212	4.9	Questionable							
	240	9.75	Nonfunctioning							
	213	11.47	Questionable							
MM2-1	221	7.25	Questionable	Undetermined (no nearby Type A logging available)	3.633 (7/15)	-7.2372 (3/15)	36.930 (7/14)	32.6540 (2/24)	Probe not responding; last readings third quarter of 2003. Many temperature readings are negative. It does not seem reasonable that soil temperatures would be negative at 7.25 ft bls.	Long-term trend is cyclic, reflecting temperature influences. Actual trend (when temperature influences are removed) is probably flat or slightly up suggesting little to no infiltration is occurring.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	241	12.51	Questionable probe functioning until August 2003	Undetermined (no nearby Type A logging available)	12.056 (1/1)	8.8593 (4/5)	58.329 (7/15)	53.6870 (2/23)	Probe not responding; last readings third quarter of 2003. The high soil temperature occurred on 1/1, which is surprising.	Long-term trend is slightly cyclic, reflecting temperature influences. Actual trend is probably fairly flat suggesting little infiltration is occurring, although it is possible that infiltration has occurred in March or April.
	231	16.00	Questionable probe functioning until August 2003	Undetermined (no nearby Type A logging available)	11.742 (7/14)	3.8004 (5/8)	58.329 (7/15)	53.8660 (6/26)	Probe not responding; last readings third quarter of 2003.	The long-term trend appears to have a slight inverse temperature effect. Data may be trending up slightly. Infiltration may have occurred at this location in the March-April timeframe.
MM2-2	220	4.00	Questionable probe functioning until August 2003	Undetermined (no nearby Type A logging available)	16.742 (7/15)	-3.2507 (2/28)	67.150 (4/5)	61.0290 (7/11)	Probe not responding; last readings third quarter of 2003. The timing of the maximum moisture content is consistent with infiltration.	Moisture trend has an inverse temperature effect. If this were removed, trend may be flat or slightly rising. If it were rising, infiltration could be occurring.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	222	9.14	Questionable probe functioning until August 2003	Undetermined (no nearby Type A logging available)	11.858 (9/12)	0.2555 (3/18)	70.749 (9/20)	51.4720 (3/14)	Probe not responding; last readings third quarter of 2003 and three readings in September. Maximum and minimum values may miss actual maximum and minimum values because half of July, all of August, and most of September data are missing.	The trend is cyclic reflecting temperature influences. However, actual trend may be rising slightly.
	224	10.78	Useful	Undetermined (no nearby Type A logging available)	10.950 (9/21)	2.2914 (8/23)	50.491 (9/28)	11.1130 (8/24)	The minimum and maximum values for temperature and moisture occurred at similar times—in August and September, which is surprising. Many data are missing.	The trend suggests there is much noise in the data. However, actual trend appears to be rising slightly. There is a possible infiltration event in the February-March timeframe. Each probe in this location seems to have a rising trend, which could indicate some water is moving through the system.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
MM2-3	246	1.67	Useful	Undetermined (no nearby Type A logging available)	25.069 (7/8)	15.4880 (9/20)	33.935 (7/1)	24.5250 (9/28)	Large data gap between early July and 9/10. High temperature and moisture data are in July data, therefore, probably do not reflect the actual high-temperature or moisture content. Moisture data have temperature component, which needs to be removed for data to be useful. The large swing in temperature results from the probe's nearness to the land surface.	The cyclic trend results from the temperature influence on the moisture data, making it a slightly muted copy of the temperature trend. The large temperature variation influences the moisture trend to such an extent that it is hard to determine the actual moisture trend, which might be fairly flat.
	215	3.05	Useful	Undetermined (no nearby Type A logging available)	18.252 (7/15)	13.2800 (9/22)	33.041 (7/15)	29.8870 (9/25)	Data collected for first half of July, then missing until 9/10. Some spurious moisture points that are outside the overall moisture trend—13.413 (9/19), 27.871 (9/19), and 22.879 (9/25) among others. These were not recorded as the minimum because they fall outside the trend. Moisture contents are influenced by temperature.	The moisture trend is cyclic, a somewhat muted mirror of the temperature trend. In the fourth quarter, the moisture trend peaks and falls off exactly like the temperature. Probably the real moisture trend is somewhat flat, but this cannot be said definitively until the temperature influence is removed from the moisture data.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	229	6.98	Questionable probe functioning until August 2003	Undetermined (no nearby Type A logging available)	11.907 (7/15)	1.1497 (3/15)	10.790 (7/11)	7.8279 (1/1)	Probe not responding; last readings third quarter of 2003.	Long-term trend is cyclic, reflecting temperature influences. If the temperature influence is removed, the trend might be slightly upward.
MM3-1	245	4.47	Useful	Undetermined (no nearby Type A logging available)	22.840 (8/5)	1.8586 (3/3)	49.414 (7/1)	35.2470 (3/9)	Data for 7/1 through 7/15 and 8/5. Rest of data (through September removed because of negative resistivities). Minimum and maximum values are of little value because of limited data set. Moisture has definite moisture influence.	Moisture trend is cyclic, reflecting the same curve as the temperature. If the temperature influence were removed, it is believed that the trend would be fairly flat, suggesting little or no infiltration.
	253	7.62	Useful	Undetermined (no nearby Type A logging available)	20.293 (8/20)	15.2400 (7/1)	14.650 (8/28)	8.3808 (2/23)	Data set is discontinuous because of removal of bad data. The moisture maximum occurs several times. Also, the maximum and minimum are not representative of entire data because some data were removed.	Cyclic, following muted temperature trend. True moisture trend appears to be rising but cannot be sure until the temperature influences are removed from the moisture data.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
5-13	242	9.69	Useful	Undetermined (no nearby Type A logging available)	19.878 (8/21)	2.6054 (3/11)	22.586 (8/20)	16.9160 (3/15)	Two data gaps in the file between 8/7 and 8/18 and 8/28 and 9/7. Minimum and maximum temperature and moisture content may not reflect true minimum and maximum. Minimum moisture content occurred frequently in early July. Maximum temperature and moisture occurred almost at the same time. Moisture content is muted reflection of temperature data.	Cyclic, following muted temperature trend. True moisture trend appears to be rising but cannot be sure until the temperature influences are removed from the moisture data. Possible spring 2002 infiltration event that is supported by nearby tensiometer data at the 10-ft level.
	MM3-2 216	3.97	Useful	Undetermined (no nearby Type A logging available)	19.510 (8/5)	-1.9673 (3/2)	21.426 (8/22)	-11.0080 (7/19)	Much of August data missing from data set. Therefore, actual minimum and maximum may be different. Soil temperature impacts the moisture data.	Because the moisture trend is impacted by the soil temperature, it is difficult to tell the true trend. It appears to be slightly up.
	252	6.96	Useful	Undetermined (no nearby Type A logging available)	19.401 (8/28)	3.4334 (3/14)	15.227 (9/27)	12.6440 (7/26)	Data set is fairly continuous through the quarter. Therefore, the minimum and maximum are probably the true minimum and maximum. Data may not be impacted by soil temperature. If it is, it is very subtle.	Trend is fairly flat, perhaps slightly up. There is enough noise in the data to have sufficient scatter to make trend analysis difficult.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	210	8.53	Useful	Undetermined (no nearby Type A logging available)	11.991 (8/22)	0.0697 (3/17)	27.904 (8/20)	21.0240 (3/18)	The data set includes data through 8/22. Soil temperature is impacting the moisture measurement. The maximum moisture occurred on 8/20, and if it could be believed, it would conclude that infiltration is occurring. However, this may not be true because the measurement reflects the rising soil temperature, not necessarily increasing moisture content.	The moisture trend is cyclic, reflecting the cyclical nature of the temperature. The true trend is probably flat.
MM3-3	254	7.46	Useful	Undetermined (no nearby Type A logging available)	22.474 (8/5)	1.2719 (3/12)	18.335 (8/5)	9.7065 (2/23)	Data set only includes data to August 5, so it is unlikely that the true maximum for temperature and moisture is captured. Soil temperature impacts the moisture data.	Cyclic, following temperature trend. Actual moisture content may be trending up slightly, but this is impossible to verify until temperature effects are removed from the moisture data.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
244	13.82	Useful		Undetermined (no nearby Type A logging available)	16.084 (9/14)	5.7843 (3/23)	8.803 (9/26)	4.3875 (3/20)	Missing data intervals include 8/7 through 8/18 and 8/28 through 9/7. Low-moisture content occurred several times during early July. High-moisture content also occurred several times in late September. The moisture content readings are influenced by soil temperature. The temperature influence must be removed before moisture content measurements can be trusted (provided the instrument is calibrated for existing soil conditions).	The moisture trend is a cyclic reflection of the temperature trend. The real moisture trend may be slightly up.
225	17.00	Useful		Undetermined (no nearby Type A logging available)	8.042 (1/22)	4.4071 (5/9)	65.688 (6/29)	58.5490 (6/2)	Data include measurements through 7/15 and one reading on 8/5. The minimum moisture content occurred numerous times in early July. The probability of capturing the actual minimum and maximum measurements in the limited data set is unlikely. Moisture is probably influenced by the temperature but more subtly than some of the other probe measurements.	Moisture trend appears to be slightly cyclic in response to soil temperature. The trend at the middle of July 2003 appeared to be slightly down or flat, but because of the missing data, nothing can be said for the trend at the end of the quarter.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
PIT5-4	289	2.81	Useful	Undetermined (no nearby Type A logging available)	28.217 (7/24)	0.3022 (3/6)	18.899 (4/23)	9.2151 (3/6)	Data set mostly complete, only missing data between 8/25 and 8/28. Minimum and maximum probably captured in data. Data appear to be influenced by temperature. Probe close to the surface so temperature reflects large swing. Because the soil is wetter on 9/21 than on 7/17, infiltration may have occurred. However, this is probably not the case, as the temperature is impacting moisture inversely. That is, when the temperature is high, moisture is low, or when the temperature is low, moisture is high. This is probably the effect of a dropping temperature.	The trend is inversely correlated to the temperature trend. Real trend may be flat, but there is also a possible infiltration event in the April-May timeframe. The timing of the maximum moisture content is consistent with infiltration.
	288	4.39	Nonfunctioning							
	279	8.18	Useful	Undetermined (no nearby Type A logging available)	20.398 (9/11)	5.7618 (3/19)	23.454 (3/6)	16.5370 (4/10)	Have entire data set. Data do not appear to be impacted by soil temperature, and suggest that slight wetting may be occurring.	Trend is slightly upward.

Table 5-1. (continued).

Table 5-11 (continued).										
Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
PIT5-TW1	285	10.16	Useful	Undetermined (no nearby Type A logging available)	18.203 (9/17)	8.2643 (4/3)	27.049 (8/30)	19.8120 (3/16)	Only small data gap (8/25 through 8/28), otherwise, data set is intact. Minimum and maximum probably captured in data. Data appear to have only a slight temperature effect. It is interesting that the high occurred about a week after the low.	Trend ever so slightly reflects the cyclic nature of the temperature. The data seem to indicate a wetting event starting toward the end of May. When temperature is removed from moisture, wetting front will be revisited. The true moisture trend appears to be rising.
	290	2.85	Useful	Undetermined (no nearby Type A logging available)	26.512 (7/25)	0.1296 (3/6)	14.320 (11/18)	8.5118 (7/14)	Data set mostly complete, only missing data between 8/25 and 8/28. Minimum and maximum probably captured in data. Data appear to be inversely influenced by temperature, notice temperature high and moisture low close to the dates. Possible wetting event in early February 2003.	Moisture trend is probably fairly flat, but temperature influence needs to be removed. Slight infiltration may have occurred in early February 2003.
	291	8.22	Useful	Undetermined (no nearby Type A logging available)	17.808 (9/11)	6.0831 (3/15)	42.919 (8/17)	41.0410 (4/2)	Entire data set exists. The high-moisture content occurred several times in late August and September. The moisture data appear to be impacted by soil temperature to a slight extent.	Although the moisture trend is slightly cyclic, reflecting soil temperature influence, the true moisture trend appears to be moving upward at a slight pace.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	282	10.24	Useful	Undetermined (no nearby Type A logging available)	14.995 (9/22)	5.9485 (3/25)	99.906 (9/28)	4.8326 (5/28)	The low-moisture content is believed to be a bad reading. Obviously, the 99 moisture content is out of the reasonable range, but the trend for moisture data may be usable if the temperature influence was removed. Possible slight wetting in February 2003.	Long-term trend is cyclic because of temperature effects. If that were removed, the trend would be moving up slightly. Possible bump in trend signifies slight wetting in February.
MM4-1	287	6.3	Probably useful							
	286	14.67	Recently useful	Soil	N/A	N/A	47.540 (8/3)	N/A	—	Perhaps up, but not enough data to determine trend.
	272	16.72	Questionable							
	233	19.44	Questionable							
MM4-2	275	4.72	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	Data available for the fourth quarter. Needs to be monitored further.	Moisture data seem to be trending upward, but this may simply be a reflection of temperature influence on the data. Data need to be monitored further before making a decision.
	273	12.08	Questionable		N/A	N/A	N/A	N/A		
	223	17.39	Questionable		N/A	N/A	N/A	N/A		
MM4-3	255	4.80	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		Not enough data to do a trend analysis.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
5-19	275	6.18	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		Not enough data to do a trend analysis.
	218	9.11	Recently questionable		N/A	N/A	N/A	N/A		
	MM4-4 257	4.17	Nonfunctioning		N/A	N/A	N/A	N/A		
	256	8.72	Questionable		N/A	N/A	N/A	N/A		
	274	10.86	Questionable		N/A	N/A	N/A	N/A		
	230	11.2	Questionable		N/A	N/A	N/A	N/A		Not enough data to do a trend analysis.
	MM4-5 239	9.74	Questionable		N/A	N/A	N/A	N/A		
	234	13.88	Questionable	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		
	SVR-12 281	4.3	Questionable	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		
	283	8.39	Questionable	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		
5-19	284	11.45	Questionable	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		Not enough data to do a trend analysis.
	SVR-20 260	4.43	Questionable	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A		

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
5-20	258	17.44	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	Insufficient FY 2003 data.	Early data appear to have an inverse temperature influence. Not enough FY 2003 data to determine a trend. Data noisy.
	259	13.79	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	Insufficient FY 2003 data.	Early data appear to have an inverse temperature influence. Not enough FY 2003 data to determine a trend. Data noisy.
	DU-8 265	6.14	Questionable		N/A	N/A	N/A	N/A		
	269	11.5	Questionable		N/A	N/A	N/A	N/A		
	270	17.86	Nonfunctioning		N/A	N/A	N/A	N/A		
	DU-14 280	4.47	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	Some data available from third quarter.	Third quarter trend seems to be flat.
	278	9.83	Questionable		N/A	N/A	N/A	N/A		
	276	15.2	Questionable		N/A	N/A	N/A	N/A		
	DU-10 263	3.97	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	The DU-10 probes have generated some data during the fourth quarter but not enough to interpret.	Not enough data to do a trend analysis.
	271	6.64	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	The DU-10 probes have generated some data during the fourth quarter but not enough to interpret.	Not enough data to do a trend analysis.

Table 5-1. (continued).

Cluster	Probe	Probe Depth (ft)	Probe Functionality	Probe Location in Subsurface Material	Temperature (°C)		Soil Moisture Content Volumetric (%)		Comments	Moisture Content Trend
					Maximum	Minimum	Maximum	Minimum		
	277	6.72	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	The DU-10 probes have generated some data during the fourth quarter but not enough to interpret.	Not enough data to do a trend analysis.
	264	9.25	Recently useful	Undetermined (no nearby Type A logging available)	N/A	N/A	N/A	N/A	The DU-10 probes have generated some data during the fourth quarter but not enough to interpret.	Not enough data to do a trend analysis.
N/A = not enough data to make reasonable picks										

## 5.6 Summary of Temperature Data

Temperature extremes and the dates they occurred for each SMR probe location are presented in Table 5-1. Temperature data for the SMR probes reflected seasonal trends. However, timing of the trends appears to be dependent upon depth. The shallower the probe, the more nearly it matched surficial air temperatures. Deeper probes had significant lag times. Shallow probes, less than 6 ft, generally had a minimum temperature in early to late March and a maximum temperature in mid-July to late August. Deep probes, greater than 13 ft, generally had a low temperature in mid-May to early June and a maximum temperature in October to early November.

The range of temperature fluctuations is also depth dependant. The largest temperature swings are in the shallow probes (less than 4 ft deep), and the smallest temperature changes are in the deepest probes (greater than 15 ft deep). Temperature impacts moisture measurements for many of the probes. In some cases, the cyclic curves of the temperature and moisture mirror each other. In other cases, the high and low peaks are reflected in the moisture data. In still other cases, the temperature and moisture are inverses of each other. It is desirable to remove the temperature impacts on the moisture data. This is usually done by applying a correction equation to the raw moisture data.

## 5.7 Issues

Several issues have emerged as crucial for maintaining and obtaining quality data. They are listed in the following headings in order of importance.

### 5.7.1 Temperature Influence on Moisture Data

The 2003 data collected from the SMR probes were analyzed quarterly (Q1, Q2, and Q3) and presented in quarterly reports. The Q2 report discussed the cyclic nature of some of the moisture data, suggesting that soil temperature might be impacting the moisture measurements.

After reviewing all of the FY 2003 data, it is believed that many of the moisture measurements are impacted by soil temperature. A good example of moisture measurements that appear impacted by temperature can be seen in Probe MM3-1-245, installed at a depth of 4.47 ft bls (see Appendix C, p. C-10). The moisture (dark blue) and the temperature (red) traces parallel each other from early 2002 through July 2003. Time is on the x-axis, while moisture content and temperature are on the y-axis. Both traces are elevated during the summer, reaching a peak in August and then falling off to a low in February. While this is reasonable for the temperature, the moisture trend would not be expected to identically mirror the temperature trend. Near surface, moisture conditions are normally wettest in March and driest in September.

Other moisture data appear to be impacted by temperature as well, even though the impact is subtle. An example of a more subtle temperature impact on moisture can be seen in Probe MM2-3-229, installed at a depth of 6.98 ft bls (see Appendix C, p. C-9). Again, dark blue represents the moisture measurements, while the red is the temperature. Here, the traces do not parallel each other, but the peak moisture readings still correspond with the maximum temperature measurements.

In other cases, temperature can influence moisture readings inversely. Probe 743-03-235, installed at a depth of 3.36 ft bls (see Appendix C, p. C-4), is an example of an inverse relationship between moisture and soil temperature. Here, the moisture (dark blue) is at a minimum when the temperature (red) is at a maximum.

Literature provided by ARA, the SMR probe developer, acknowledges the temperature effects on soil moisture but suggests that unless the temperature significantly exceeds the range of 10°C to 30°C, the effect is expected to be negligible (Conklin et al. 1999). The ARA further states that they have found the soil moisture sensor to be sensitive to the known variation of dielectric permittivity with temperature (ARA 2003). The literature from ARA also provides an equation that should remove the temperature effects when it is applied to the raw data. The ARA tested the SMR probe in a variety of soils of differing textures, organic contents, and controlled moisture conditions to develop a calibration equation that relates the dielectric-proportional probe response to volumetric soil moisture. When contacted, the ARA representative provided the equation and indicated that if it did not remove the temperature influences, he was willing to work with the INEEL to develop a Site-specific equation that, when applied to the raw moisture readings, should remove the temperature effects. The difficulty is that no raw data are being collected. An attempt to back-calculate the raw data for equation application and potential use in development of the Site-specific equation has been made. However, it is strongly recommended that several dataloggers be programmed to collect the raw data as well as processed data for the next quarter. With both raw and processed data, the equation can be developed and tested for removing the temperature from the moisture data. When the equation is validated, it can be added to the processing.

### **5.7.2 Resistivity Measurements**

The quarterly reports have been reporting resistivity values measured by the SMR probes. The Q2 report states that the trend in resistivity data should be opposite that of the moisture content data. That is, as the moisture content increases, the soil becomes more conductive, and resistance decreases. Further, the report states that the consistency between the resistivity and soil moisture data is not clear because the resistivity data exhibit significant variability. Variability in resistivity may result from the above moisture-temperature issue, from salinity changes, or from RWMC clays. The SMR probes were evaluated at the INEEL using RWMC soil. The conclusion was that the resistivity data proved to be so erratic as to be meaningless for INEEL applications. These observations lead to the recommendation to discontinue reporting resistivity data (therefore, that data are not included in this report). Should temperature effects be successfully removed from the SMR data, the utility of the resistivity data can be revisited.

### **5.7.3 Trend Reporting**

Past practices have been to remove data from the data set that were considered bad (e.g., negative moisture and extreme temperatures). It is recognized that negative moisture cannot occur, but if trends and not absolute values are looked at, the trends of the negative moisture might be good while the actual values are not. In the future, it is our intent to look at the trends of the negative moisture values to determine if there is usable data that can be extracted.

### **5.7.4 Nonfunctioning Probes**

During the fourth quarter (FY 2003) and continuing into FY 2004, the design engineer has worked with the SMR probes to resolve problems. Work included the following activities:

- SMR probes were individually interrogated to collect readings and determine functionality.
- All dataloggers have been reprogrammed with calibrations for the SMR probes that had corrupt calibrations.
- SMR probe communication wiring was reconfigured so that each probe is on an individual RS-485 driver. This corrected communication problems originating from star-patterned topology.

This work resulted in successfully bringing several clusters of SMR probes back online that had not been functioning for a long period. These probes are listed at the end of Table 5-1, with “N/A” designating their minimum and maximum temperature and moisture content values. Because they have just recently come back online, so little data were available that it was not considered meaningful to present minimum and maximum data points.

#### **5.7.5 Salinity**

Salinity increases or changes may be impacting the moisture content as well as the resistivity. It might prove beneficial to conduct laboratory tests to evaluate the salinity and resistivity impact on moisture content.

### **5.8 Recommendations**

The following recommendations are critical to ensure integrity of the project and quality data:

- Collect raw and processed data from the SMR probes for FY 2004
- Develop and apply a temperature correction equation to the moisture probe measurements
- Calibrate SMR probes with the neutron probe in areas where Type A probes or neutron access tubes exist
- Perform controlled experiments to determine impact of soil resistivity and salinity on moisture measurements.

## 6. VISUAL PROBE

### 6.1 Introduction

Visual probes, as shown in Figures 1-1 and 1-2, are constructed from steel rods, stabilizers, tool joints, and Lexan tubes. The steel rods, stabilizers, and tool joints form a framework inside the Lexan tube that becomes sections of the visual probe. The first section of a visual probe has a drive point and is advanced into the ground using a sonic drill rig. Additional sections, 4 ft long, are added to the visual probe as needed to reach the required depth. The interior of the probe then provides access to the interior of the landfill or subsurface soil structure, and the waste or soil structure can be viewed through the clear Lexan tube. The *OU 7-13/14 Integrated Probing Project Type B Probes Visual Probe Design* (Clark 2001b) describes the construction and design specifications of the visual probes installed for this program.

Ten visual probes were placed in the SDA. Three each were placed in the organic sludge focus area (743), the DU focus area, and the Pit 9 focus area (P9). One was placed in the americium and neptunium focus area (741). The locations of the probes are shown in the figures in Appendix A, and the detailed data for each probe are contained in Appendix B (see Table B-1 in Appendix B).

### 6.2 Methods

The procedure for logging video probes is "Visual Probe Logging Procedure" (TPR-1671). This procedure uses a commercially available borehole camera and records the visual images on standard VHS videotapes. The borehole camera uses a small-diameter fiber-optic cable that is lowered down the visual probes. The end of the fiber-optic cable has a lens and light source, and the end can be articulated or bent up to approximately a horizontal position to see the side of the hole through the Lexan tube. The borehole camera was not used in FY 2003 to record images from the visual probes. The previous videotape borehole logs are available in the project files and the Hydrologic Data Repository.

In September 2002 and March 2003, the visual probes were logged with an optical televiewer by a technical services contractor. The optical televiewer is a visual logging tool that can take a picture of the entire 360-degree interior of the visual probe in thin horizontal slices. The horizontal slices are placed in a digital file to create a complete visual record of the interior of the probe. The optical televiewer uses a rotating mirror in the end of the tool to illuminate the wall of the borehole and take the circumferential pictures. The images are displayed by splitting the image longitudinally and laying the image out flat, similar to cutting a tube longitudinally and opening the tube up and placing it flat on a table with the interior surface facing up. All of the visual probes were logged with the optical televiewer, except for Cluster 743-18V and the visual probes in Pit 9 (see Figure A-4 in Appendix A). The visual probes in Pit 9 were not logged because construction activities for the retrieval demonstration prevented access to the probes. The images are available on CD in the project files; on a share drive, Hbb2/optical\_televiewer; or in *Compilation of Analytical Notes and Data Analyses for the Integrated Probing Project 1999–2002* (Josten 2002). The images recorded in March 2003 are in Appendix E.

### 6.3 Results

Logging with the borehole camera evolved into an effective technique to observe and evaluate subsurface waste and soil structure. To start the logging efforts, technicians learned how to use and operate the borehole camera system and were challenged to find ways to produce steady images with a thin fiber-optic cable hanging down the inside of the visual probes. They gained experience operating the system and developed a way to stabilize the fiber-optic cable by running it through a PVC pipe that

lessened movement of the end of the cable and provided directional control. The borehole camera provides good microscale images of the borehole interior.

The optical televiewer provides a good macroscale image of the interior of the visual probes. The image of Probe 741-08-V shows the cover soil over the americium and neptunium focus area in Pit 10 (see Figure A-5 in Appendix A). Near the bottom of the log, a layer of yellow and translucent waste is shown, which is probably personal protective equipment. Probes 743-03-V, 743-08-V, and 743-18-V are in the organic sludge focus area in Pit 4. The log of Probe 743-03-V shows a change in soil texture between 5 and 7 ft and a distinct change in soil color below 7 ft that can be attributed to the presence of waste. The log for Probe 743-08-V has recorded some very distinct waste near the bottom of the hole that appears to be light blue in color and cloudy or translucent. It's difficult to determine what this waste could be, but it may be some translucent plastic sheeting the probe has penetrated. Discoloration of the Lexan also could be caused by carbon tetrachloride degradation of the polycarbonate. Probe 743-18-V cannot be logged because rust and corrosion on the inside of the probe collect on the clear plastic window of the optical televiewer and make it impossible to get a good image. Probes DU-08-V, DU-10-V, and DU-14-V are in the DU focus area in Pit 10. The log of Probe DU-08-V shows overburden soil down to a depth of about 7 ft, where a white object can be seen in the soil. Below this depth, the color changes to a lighter brown, and darker-colored objects and fragments can be seen to the bottom of the probe. Probe DU-10-V is a short probe and shows a distinct change in soil color at a depth of approximately 7 ft, which may be the overburden and waste interface. The log for Probe DU-14-V has dark areas showing up in the soil below a depth of 7 ft and below 10 ft down to the bottom of the probe. At about 1 ft more, several dark images are seen that may be fragments or large pieces of waste. The depths in the optical televiewer logs are based on the collar of the probe and have not been adjusted for probe stickup.

## **6.4 Conclusions**

The visual probes are a useful tool to gain access to and record images of the subsurface soil and waste. The visual probes coupled with the optical televiewer provide information that can define waste and soil interfaces, changes in color in the waste and soil matrix, and images of waste fragments and pieces. The borehole camera provides images on a much smaller scale and is useful for examining smaller features and details in the borehole. The visual probes have provided a unique opportunity to physically see the soil and waste in selected parts of the SDA. While current plans for remedial activities do not include use of the visual probes, they can be used again if experience with ongoing activities indicates visual probes would be beneficial.

## **7. TYPE A PROBE**

### **7.1 Methods**

Forty-eight new Type A probes were installed during FY 2003. Much of the first half of the year was spent planning probe locations, using waste inventory records and surface geophysics data. New probes were installed in August–September and were logged beginning in September using a nuclear logging suite consisting of passive spectral gamma-ray, passive neutron, neutron-activated spectral gamma-ray, and moisture logging methods. Logging data from the first 37 new probes were received from the subcontractor near the end of FY. Preliminary analysis was conducted, which consisted of identifying contamination areas and comparing contamination type with waste inventory information. The investigation of quantitative analysis methods for estimating VOC chlorine mass continued throughout the year. This work focused on calibration of the neutron-activated spectral gamma-ray tool under variable conditions. At the beginning of FY 2004, a major effort was begun to collect and archive all the SDA surface and downhole geophysical data into a permanent on-Site archive.

### **7.2 Results**

The following list of FY 2003–early FY 2004 logging program activities reflects an effort to capture and document the status and history of the program through the end of January 2004.

#### **7.2.1 Comprehensive Logging and Surface Geophysics Data Analysis Summary—October to December 2002**

Results and notes from previous unpublished analysis efforts pertaining to Type A probe selection, installation, logging, and interpretation were published in December 2002 in *Compilation of Analytical Notes and Data Analyses for the Integrated Probing Project 1999–2002* (Josten 2002). The report contains numerous summaries and discussions of probe planning and probing results for the first 148 Type A probes installed at the SDA. Appendix A of *Compilation of Analytical Notes and Data Analyses for the Integrated Probing Project 1999–2002* also contains a previously unpublished surface geophysics report for SDA Pits 4, 6, and 10.

#### **7.2.2 Select and Screen New Fiscal Year 2003 Type A Probes—December 2002 to April 2003**

Eight new study areas were identified for exploration with new Type A probes in FY 2003. The screening process for these study areas consisted of the following activities:

- Selecting waste shipments of interest using the INEEL WasteOScope database system
- Evaluating surface geophysics and selecting preliminary Type A probe locations
- Identifying inconsistencies or uncertainties between the waste inventory data and the surface geophysics
- Selecting those study areas and probe locations judged to have the best chance of achieving the program objective.

New high-resolution geophysical data were collected to support final probe selection (see Section 7.2.4). After several revisions and review by program management and participating federal and state agencies, 37 new probes were planned for eight study areas as summarized in Table 7-1 and Figure 7-1.

### 7.2.3 Technical Specifications for Fiscal Year 2003 Geophysical Logging—February to March 2003

A technical specification (SOW-561) describing subcontractor requirements for geophysical logging of the new probes was prepared. The technical specification was based on the specification used to procure logging services in previous SDA logging campaigns so that the data would be comparable to earlier results. Data processing, tool calibration, and data delivery requirements were refined to improve the long-term utility of the data. The new specification required vendor data submittals for the purpose of documenting work procedures, tool calibration certificates, tool designs, and data processing methodology. These items will be needed by the INEEL if detailed quantitative analysis is desired in the future.

### 7.2.4 Surface Geophysics Surveys—July to August 2003

The effort to select new FY 2003 study areas and Type A probe locations used surface geophysics data to attempt to identify the approximate position of targeted waste shipments. New high-resolution magnetic and time-domain electromagnetic surveys were conducted to support probe selection for Study Areas 1A, 1B, 1C, and 1D as shown in Figure 7-2. (Note that no probes were installed in Study Area 1C during the initial FY 2003 campaign [because of a scope reduction].)

Table 7-1. Summary of new Fiscal Year 2003 Type A probe study areas.

Study Area	Location	Target Waste Type	Number of Probes	Probes
1A	Trench 3	Enriched uranium	4	T3-UE-01, T3-EU-02, T3-EU-03, and T3-EU-04
1B	Trench 47	Irradiated fuel	4	T47-IF-1, T47-IF-2, T47-IF-3, and T47-IF-4
1D	Outside known pits and trenches	Undocumented disposals	9	UD-01, UD-03, UD-03B, UD-04, UD-05, UD-05B, UD-05C, UD-05D, and UD-05E
2	Trench 24	High-activity liquid	4	HAL-1, HAL-2, HAL-3, and HAL-4
3	Pit 5	Uranium and enriched uranium	8	P5-UEU-1, P5-UEU-2, P5-UEU-3, P5-UEU-4, P5-UEU-5, P5-UEU-6, P5-UEU-7, and P5-UEU-8
4	Pit 10	Plutonium in vicinity of Cluster 741-08	2	741-10 and 741-11
5	Pit 6	Plutonium	3	P6-PU-1, P6-PU-2, and P6-PU-3
6	Pit 10	Plutonium	3	P10-PU-1, P10-PU-2, and P10-PU-3

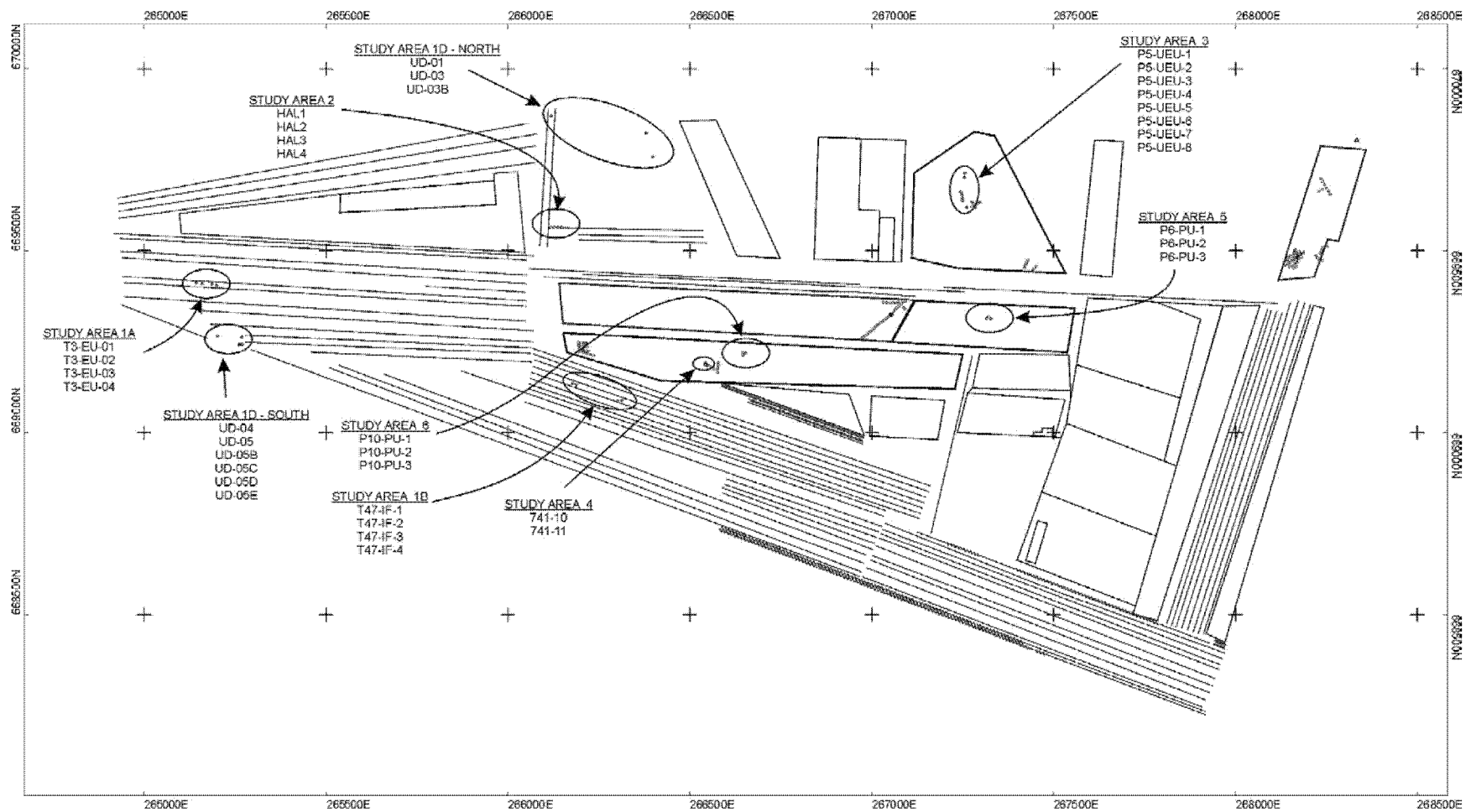


Figure 7-1. Index map for Fiscal Year 2003 Type A study areas and probes.

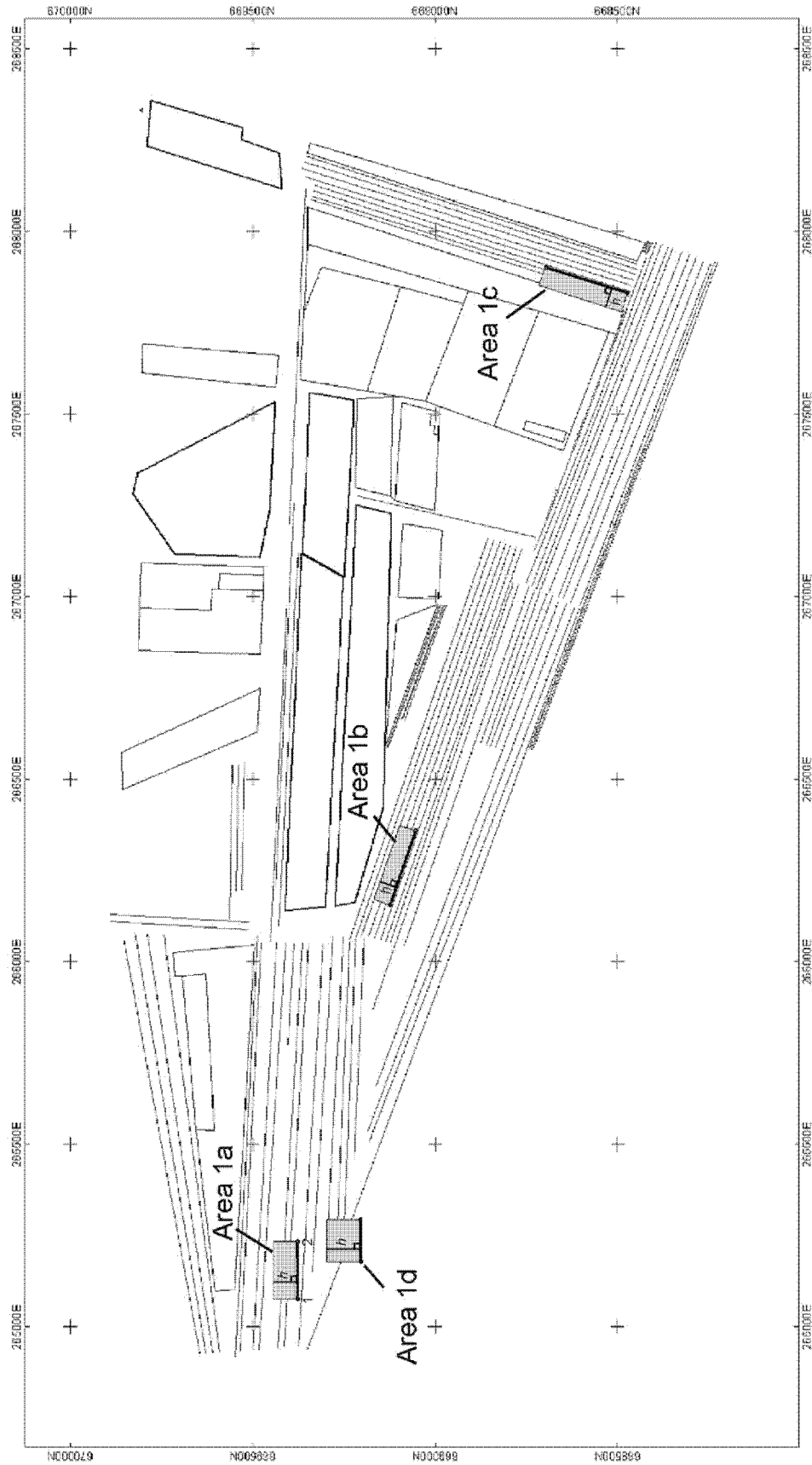


Figure 7-2. Index map Fiscal Year 2003 surface geophysics surveys used to support study area and probe selection.

Waste shipment manifests contain information regarding the types and quantities of waste containers and the composition of waste masses. Typically, the geophysical data serve to identify the presence or absence of metallic containers or massive metal objects and are therefore useful for identifying probe locations that are consistent with waste manifest information.

### **7.2.5 Analysis of Chlorine Logging Data for Organic Contamination in the Vadose Zone—July to October 2003**

In FY 2002, the Organic Contamination in the Vadose Zone Project initiated a program to analyze Type A logging data for the purpose of quantifying VOC levels within SDA buried waste. The draft document produced from this effort, “Preliminary Estimate of Carbon Tetrachloride and Total Volatile Organic Carbon Compound Mass Remaining in Subsurface Disposal Area Pits (Draft),”<sup>a</sup> is still in technical review. The Organic Contamination in the Vadose Zone Project is resolving technical issues inherent to the problem of quantifying VOC levels using geophysical logging data. The FY 2003 efforts were focused on logging-tool calibration under highly heterogeneous subsurface conditions. Preliminary work has shown that hydrogen content and bulk density can have pronounced effects on the logging tool response to chlorine. Corrections for these effects are being sought.

### **7.2.6 Analysis of Moisture Logs—September to October 2003**

Results from FY 2003 soil moisture logs in several new probes indicated volumetric soil moisture contents exceeding 30 vol% within the first few feet of the subsurface. The moisture content results were considered unusual because of recent excessively dry conditions at the SDA. A soil sampling effort was initiated to verify the moisture results.

Laboratory moisture measurements of the verification soil samples generally agreed with the logging results and serve to validate the moisture logging tool performance and calibration. Details of this moisture study may be obtained by INEEL internal correspondence.<sup>b,c,d</sup> Soil sampling results in weight percent are listed in Table 7-2, along with a computed value for the corresponding volume percent to facilitate comparison with moisture logging data. The conversion between weight percent and volume percent depends on the soil dry bulk density, which was taken as 1.44 g/cc based on previous SDA soil sampling data (McElroy and Hubbell 1990).

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a. INEEL, 2004, “Preliminary Estimate of Carbon Tetrachloride and Total Volatile Organic Carbon Compound Mass Remaining in Subsurface Disposal Area Pits (Draft),” INEEL/EXT-02-00140, Rev. B, Idaho National Engineering and Environmental Laboratory.

b. T. J. Meyer, INEEL, Memorandum to J. L. Casper, INEEL, “Soil Sampling for Nuclear Logging Soil Moisture Verification,” September 4, 2003.

c. Carol Strong, INEEL, Memorandum to T. J. Meyer, INEEL, “Soil Sampling for Nuclear Logging Soil Moisture Verification,” September 15, 2003.

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Table 7-2. Summary of sampling and logging results.

Well_ID	Sample_ID	Depth	Soil Sampling Weight Percent	Soil Sampling Volume Percent	Nuclear Logging Volume Percent
P5-UEU-4	SMV00601M7	1	19.5	28.1	19.2
P5-UEU-4	SMV00701M7	2	22.2	32.0	32.2
P5-UEU-4	SMV00801M7	3	24.5	35.3	32.0
UD-01	SMV00301M7	1	13.4	19.3	16.2
UD-01	SMV00401M7	2	16.6	23.9	22.2
UD-01	SMV00501M7	3	19.3	27.8	22.3
HAL1	SMV00001M7	1	8.4	12.1	7.0
HAL1	SMV00101M7	2	7.9	11.4	8.5
HAL1	SMV00201M7	3	6.8	9.8	11.5

#### 7.2.7 Analysis of Type A Logging Data for Areas 1A, 1B, 1D, 2, 3, 4, 5, and 6—September to November 2003

This report gives a brief summary of downhole logging results for the 37 new probes installed during FY 2003. These study areas are located in the western half of the SDA as shown in Figure 7-1. Table 7-3 gives a summary, by probehole, of the logged depths for each of the four logging tools employed. (Minimum and maximum logging depths are given in feet below ground surface.)

The man-made radionuclides are segregated into three groupings: cobalt, cesium, and europium; plutonium, americium, and neptunium; and uranium. These groupings characterize distinct waste streams. The other common waste constituent, chlorine, is shown in the chart summaries together with hydrogen because the logging tool response to these elements is known to be highly interdependent. A detection summary for the common man-made radionuclides and chlorine is presented in Table 7-4. (Value displayed corresponds to the highest apparent concentration observed in each probehole.)

Table 7-3. Logging completion summary for new Fiscal Year 2003 probes.

Study Area	Probe	Passive Neutron		Passive Gamma		N-Gamma		Moisture	
		Minimum (ft bgs)	Maximum (ft bgs)	Minimum (ft bgs)	Maximum (ft bgs)	Minimum (ft bgs)	Maximum (ft bgs)	Minimum (ft bgs)	Maximum (ft bgs)
1A	T3-EU-01	2.30	17.60	2.0	18.00	2.0	16.90	0.30	18.10
1A	T3-EU-02	2.30	20.90	2.0	21.40	2.0	20.30	0.30	21.40
1A	T3-EU-03	2.30	11.00	2.0	11.40	2.0	10.30	0.30	11.50
1A	T3-EU-04	2.30	12.60	2.0	12.20	2.0	11.90	0.30	13.10
1B	T47-IF-1	2.30	10.70	2.0	11.10	2.0	10.00	0.30	11.10
1B	T47-IF-2	2.30	9.90	2.0	10.30	2.0	9.30	0.20	10.40
1B	T47-IF-3	2.30	10.70	2.0	11.00	2.0	10.00	0.20	11.10
1B	T47-IF-4	2.30	8.80	2.0	9.20	2.0	8.20	0.20	9.30
1D	UD-01	2.24	9.58	2.0	10.02	2.0	8.95	0.25	10.13
1D	UD-03	2.25	3.65	2.0	4.04	2.0	3.03	0.25	4.13
1D	UD-03B	2.25	13.84	2.0	14.22	2.0	13.22	0.25	14.33
1D	UD-04	2.25	13.40	2.0	13.86	2.0	12.81	0.25	13.91
1D	UD-05	2.25	3.62	2.5	4.03	2.0	2.83	0.25	4.13
1D	UD-05B	2.25	4.13	2.0	4.49	2.0	3.48	0.25	4.60
1D	UD-05C	2.25	4.42	2.0	4.80	2.0	3.75	0.25	4.86
1D	UD-05D	2.25	4.56	2.0	4.92	2.0	3.92	0.25	5.00
2	HAL-1	2.30	19.20	2.0	19.70	2.0	18.60	0.30	19.70
2	HAL-2	2.30	21.60	2.0	22.00	2.0	21.00	0.20	22.10
2	HAL-3	2.30	7.80	2.0	8.20	2.0	7.10	0.30	8.20
2	HAL-4	2.30	12.00	2.0	12.50	2.0	11.40	0.30	12.50
3	P5-UEU-1	4.24	17.60	4.0	18.11	4.0	17.12	0.25	18.16
3	P5-UEU-2	4.23	17.30	4.0	17.76	4.0	16.68	0.25	17.75
3	P5-UEU-3	4.24	15.24	4.0	15.74	4.0	14.66	0.25	15.80
3	P5-UEU-4	4.25	16.80	4.0	17.27	4.0	16.18	0.25	17.29
3	P5-UEU-5	4.25	15.26	4.0	15.70	4.0	14.66	0.25	15.79
3	P5-UEU-6	4.24	15.06	4.0	15.51	4.0	14.46	0.25	15.57
3	P5-UEU-7	4.25	16.19	4.0	16.64	4.0	15.54	0.25	16.71
3	P5-UEU-8	4.25	11.26	4.0	11.72	4.0	10.64	0.25	11.74
4	741-10	4.24	19.20	4.0	19.67	4.0	18.56	0.25	19.69
4	741-11	4.25	19.32	4.0	19.73	4.0	18.66	0.25	19.76
5	P6-PU-1	4.25	19.59	4.0	19.89	4.0	18.82	0.25	19.92
5	P6-PU-2	4.25	19.43	4.0	20.06	4.0	19.02	0.25	20.05
5	P6-PU-3	4.25	7.38	4.0	7.80	4.0	6.74	0.25	7.88
6	P10-PU-1	4.24	5.10	4.0	5.54	4.0	4.48	0.25	5.58
6	P10-PU-2	4.24	9.60	4.0	10.07	4.0	8.97	0.25	10.10
6	P10-PU-3	4.25	19.86	4.0	20.31	4.0	19.26	0.24	20.50

Table 7-4. Contamination detection summary for new Fiscal Year 2003 probes.

Study Area	Probe	Cs-137 (pCi/g)	Co-60 (pCi/g)	Eu-154 (pCi/g)	Pu-239 (nCi/g)	Am-241 (nCi/g)	Np-237 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	Chlorine (counts/second)
1A	T3-EU-01	3.2	5.0	ND	ND	ND	ND	ND	ND	2.9
1A	T3-EU-02	5,504.8	1.0	ND	ND	ND	ND	26.5	1,235.7	8.0
1A	T3-EU-03	31.7	ND	ND	ND	ND	ND	3.4	178.8	2.0
1A	T3-EU-04	0.3	ND	ND	ND	ND	ND	ND	22.9	1.2
1B	T47-IF-1	1,942.9	3.4	14.3	ND	ND	ND	ND	ND	1.1
1B	T47-IF-2	2,295.5	13.2	4.8	ND	ND	ND	ND	ND	1.2
1B	T47-IF-3	3.2	24.6	ND	ND	ND	ND	ND	ND	ND
1B	T47-IF-4	8.9	0.2	ND	ND	ND	ND	ND	ND	1.4
1D	UD-01	ND	ND	ND	ND	ND	ND	ND	ND	2.3
1D	UD-03	ND	ND	ND	ND	ND	ND	ND	ND	ND
1D	UD-03B	ND	ND	ND	ND	ND	ND	ND	ND	1.1
1D	UD-04	42.1	157.7	ND	ND	ND	ND	ND	ND	1.3
1D	UD-05	ND	ND	ND	ND	ND	ND	ND	ND	0.9
1D	UD-05B	0.5	ND	ND	ND	ND	ND	ND	ND	ND
1D	UD-05C	0.3	ND	ND	ND	ND	ND	ND	ND	ND
1D	UD-05D	0.4	ND	ND	ND	ND	ND	ND	ND	ND
1D	UD-05E	1.9	ND	ND	ND	ND	ND	ND	ND	2.3
2	HAL-1	0.3	ND	ND	ND	ND	ND	ND	ND	0.6
2	HAL-2	6,773.5	228.0	5.5	ND	ND	ND	ND	ND	1.0
2	HAL-3	1.0	ND	ND	ND	ND	ND	ND	ND	ND
2	HAL-4	240.7	45.8	ND	ND	ND	ND	ND	ND	ND
3	P5-UEU-1	ND	0.3	0.8	3,074.7	872.5	12.2	ND	ND	38.7
3	P5-UEU-2	ND	ND	2.5	1,272.7	3,701.0	52.5	ND	363.8	4.9
3	P5-UEU-3	ND	ND	4.6	5,331.0	1,340.8	21.4	10.5	940.6	20.4
3	P5-UEU-4	ND	ND	4.6	31,924.9	7,469.7	96.5	26.4	2,102.5	34.6
3	P5-UEU-5	ND	ND	5.1	3,214.0	6,153.0	87.7	109.3	32,920.6	1.9
3	P5-UEU-6	ND	ND	10.5	2,399.7	4,114.9	62.3	ND	63.4	5.2
3	P5-UEU-7	ND	ND	1.8	1,180.1	1,842.6	26.4	2.8	ND	24.2
3	P5-UEU-8	1.7	ND	ND	219.0	ND	ND	ND	29.1	6.2
4	741-10	ND	ND	ND	ND	ND	ND	173.1	174.6	10.5
4	741-11	ND	ND	ND	ND	ND	ND	12.0	74.8	6.1
5	P6-PU-1	ND	ND	12.9	7,943.8	42,117.8	593.7	ND	573.8	5.3
5	P6-PU-2	ND	ND	1.0	1,590.9	1,129.6	12.1	ND	28.1	2.8
5	P6-PU-3	ND	ND	3.6	1,234.1	551.0	8.1	ND	ND	ND
6	P10-PU-1	ND	ND	ND	ND	ND	ND	ND	ND	1.3
6	P10-PU-2	ND	ND	ND	ND	ND	ND	ND	ND	14.6

Table 7-4. (continued).

Study Area	Probe	Cs-137 (pCi/g)	Co-60 (pCi/g)	Eu-154 (pCi/g)	Pu-239 (nCi/g)	Am-241 (nCi/g)	Np-237 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	Chlorine (counts/second)
6	P10-PU-3	ND	ND	ND	21.3	ND	ND	ND	ND	8.7
	MAX <sup>a</sup>	140.5	814.2	N/A	194,171.0	30,449.0	4,881.0	344.9	220,894.0	38.0
	PROBE	741-04	P9-FI-05	N/A	P9-20	743-08-02	DU-08	743-08	743-08	P9-03

a. Maximum observed value of radionuclide or element from previous Subsurface Disposal Area logging; no previous data available for Eu-154.

ND = nondetect

In general, logging results from the FY 2003 probes showed the same characteristics as have been observed in previous SDA logging. The same common radionuclide groupings—plutonium, americium, and neptunium; U-235 and U-238; and cesium and cobalt—that had been observed were prevalent throughout the new probes as well. The apparent radionuclide concentrations also were comparable, except that very high levels of Cs-137 were detected in several probes. Chlorine was widely detected throughout all the study areas, a finding that has been characteristic of all the SDA logging performed to date.

The following items are considered noteworthy:

- The logging data suggest the presence of enriched uranium in Probes P5-UEU-7, 741-10, and 741-11.
- High levels of Cs-137 and Co-60 were observed in Probes T3-EU-02, T47-IF-1, T47-IF-2, HAL-2, and HAL-4. The spectral gamma-ray detector was saturated by the high gamma-ray flux in HAL-2, and it was not possible to identify the peak contamination depth.
- Eu-154 was identified in many of the FY 2003 probeholes, where it was commonly associated with plutonium, americium, and neptunium contamination zones.
- High levels of natural potassium, uranium, and thorium were observed sporadically throughout the FY 2003 probes. As yet, no pattern or explanation has been proposed for these anomalies.

## 7.2.8 Analysis of Azimuthal Logging Data—December 2003 to January 2004

Azimuthal logging was conducted in 13 probes during November–December 2003 (see Table 7-5). Azimuthal logging is conducted with a hyper-pure germanium, gamma-ray detector contained within a slotted shield. During logging, the tool (and therefore the slot) is rotated through 360 degrees of azimuth, and a gamma-ray spectrum is acquired at 22.5-degree increments. The purpose of azimuthal logging is to detect heterogeneous radionuclide distributions as indicated by variation in gamma-ray flux with azimuthal direction. Logging depth is held constant during the azimuthal survey. In some cases, azimuthal surveys were conducted at multiple depths in a probehole. Fifty-seven azimuthal surveys were conducted during the November–December logging effort.

Table 7-5. Azimuthal logging data acquisition summary.

Study Area	Location	Target Waste Type	Probe	Probe Depth
1A	Trench 3	Enriched uranium	T3-EU-02	8.0
1A	Trench 3	Enriched uranium	T3-EU-03	8.0
1B	Trench 47	Irradiated fuel	T47-IF-1	8.0
1B	Trench 47	Irradiated fuel	T47-IF-2	8.0 and 10.0
2	Trench 24	Liquid waste	HAL-2	12.0 and 21.0
2	Trench 24	Liquid waste	HAL-4	12.0
3	Pit 5	Uranium and enriched uranium	P5-UEU-1	8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 15.5, and 16.0
3	Pit 5	Uranium and enriched uranium	P5-UEU-4	6.0, 7.0, 8.0, 9.0, 9.5, 10.0, 11.0, 12.0, 13.0, and 14.0
3	Pit 5	Uranium and enriched uranium	P5-UEU-5	11.0, 12.0, and 13.0
3	Pit 5	Uranium and enriched uranium	P5-UEU-7	10.0, 11.0, 12.0, 13.0, and 14.0
5	Pit 6	Plutonium waste	P6-PU-1	6.0, 7.0, 8.0, 9.0, 10.0, 11.0, and 12.0
5	Pit 6	Plutonium waste	P6-PU-2	9.0, 10.0, 11.0, 12.0, 13.0, and 14.0
5	Pit 6	Plutonium waste	P6-PU-3	7.74

Table 7-6 lists interpreted azimuthal peaks for the logs obtained during the FY 2003 logging campaign. The nuclides causing the azimuthal peaks and the quality of the peak are indicated along with the interpreted azimuth direction. The azimuthal peak characteristics may be used to precisely position additional Type A or Type B probes to investigate contaminants of interest.

Azimuthal logs were collected at 0.5-ft intervals from 8 to 16 ft in Probe P5-UEU-1. These logs provide useful insight into the heterogeneity of the SDA subsurface since they make it possible to observe the change in position of the radionuclide source with depth. The Probe P5-UEU-1 data reveal that approximate homogenous conditions occur at a few depths, but most depths indicate heterogeneous conditions (i.e., the waste containing the radionuclide source is not uniformly distributed about the probehole). The data also show that the direction, radionuclide mixture, and apparent radionuclide concentrations change gradually with depth. Heterogeneity may be caused by nonuniform radionuclide distribution or nonuniform density distribution in the vicinity of the probehole.

Table 7-6. Azimuthal logging data results summary.

Probe	Probe Depth	Azimuth (degrees)	Nuclide	Peak Quality
T3-EU-02	8.0	169	U-238	Fair
T3-EU-03	8.0	None	U-238	Poor
T47-IF-1	8.0	290	Cesium and minor cobalt	Good
T47-IF-2	8.0	290	Cesium and minor cobalt	Good
T47-IF-2	10.0	124	Cesium and minor cobalt	Good
HAL-2	12.0	191	Cesium and minor cobalt	Good
HAL-2	21.0	90	Cesium and minor cobalt	Fair
HAL-4	12.0	90	Cesium and cobalt	Fair
P5-UEU-1	9.0	280	Plutonium	Good
P5-UEU-1	14.5	45	Plutonium	Fair
P5-UEU-4	9.0	11	Plutonium and americium	Good
P5-UEU-4	10.0	90	Plutonium and americium	Good
P5-UEU-4	12.0	0	Americium	Poor
P5-UEU-4	14.0	135	U-238	Poor
P5-UEU-5	12.0	236	Plutonium, americium, and neptunium	Fair
P5-UEU-7	11.0	68	Plutonium	Fair
P6-PU-1	8.0	34	Americium, neptunium, and plutonium	Good
P6-PU-1	8.0	68	U-238	Poor
P6-PU-1	10.0	90	Plutonium	Fair
P6-PU-2	10.0	168	Americium	Fair
P6-PU-2	10.0	338	Americium	Poor
P6-PU-2	13.0	260	Plutonium	Fair
P6-PU-3	7.7	185	Plutonium and neptunium	Good

### 7.2.9 Long-Count Spectral Gamma-Ray Data—December 2003 to January 2004

Four special passive spectral gamma-ray logging measurements were collected in Probes P6-PU-1 and P6-PU-2. These measurements used 3,000-second count times in order to increase the sensitivity to target radionuclides compared with standard 300-second counts (see Table 7-7). The purpose of these measurements was to investigate evidence for downward migration of radionuclides from waste stream contamination zones to the underlying soil. For each probe, one measurement was obtained at the waste-soil interface, and a second measurement was made 1 ft deeper into the underburden.

Table 7-7. Estimated detection limits.

Radionuclide	Energy (keV)	Detection Limit @ 300 seconds <sup>a</sup> (pCi/g)	Detection Limit @ 3,000 seconds <sup>b</sup> (pCi/g)
Np-237	312	1	0.32
Pu-239	375	25,000	7,906.00
Am-241	662	43,000	13,598.00
Am-241	722	90,000	28,460.00
U-238	1,001	10	3.16

a. Based on minimum detection limits calculated for low-contamination zones in Probe P6-PU-1.

b. Scaled based on square root of count time.

The long-count measurements showed that, with a single exception, no radionuclides were detectable at the deeper measurement point. The single exception was Am-241, which was detected at just above the detection limit in Probe P6-PU-1. Overall, the measurements suggest that contaminant migration into soil beneath the waste zone is extremely limited.

## 7.2.10 Idaho National Engineering and Environmental Laboratory Geophysical Database Compilation—October 2003 to January 2004

Beginning in October 2003, the OU 7-13/14 Remedial Investigation/Feasibility Study Project initiated a comprehensive effort to consolidate, organize, and archive all the existing surface and downhole geophysical data for the SDA. At present, the data are archived by the program in hard-copy format only. Over the preceding years, several informal databases were developed to support data analysis, but the database formats are inconsistent and do not contain all the data that have been collected at the SDA. The database compilation effort will result in the permanent storage of these data in an INEEL database where they will be readily accessible for future uses.

Two separate databases have been developed in prototype form: one for geophysical logging data collected from 1999 to 2003 and one for surface geophysics data collected between 1992 and 2003. The logging database has been populated with data from the first 148 probes installed and logged at the SDA. The database will contain analysis results, calibration records, and raw data files for every measurement since the inception of the Type A logging program in 1999. All new logging data will be archived in this database.

The surface geophysics database has been populated with data from 41 geophysical surveys. Twelve additional datasets have been recovered from informal archives and are ready for transfer to the new database. Five known surveys have not yet been recovered in electronic format. The database contains magnetic and electromagnetic survey data collected using a variety of different equipment and methods. Details concerning equipment and data acquisition methods will be stored with the data.

The “Geophysics Logging and Surface Information System Configuration Management Plan for the OU 7-13/14 Project (Draft)”<sup>e</sup> contains the database specifications, quality assurance/quality control results, and maintenance plans for these new databases.

e. PLN-1568, 2004, “Geophysics Logging and Surface Information System Configuration Management Plan for the OU 7-13/14 Project (Draft),” Rev. B, Idaho National Engineering and Environmental Laboratory.

## 7.3 Discussion

The process of using WasteOScope (the SDA waste inventory database) and surface geophysics data for selecting probe locations in order to investigate specific items of waste inventory has been shown to be effective in most cases, but not all. In particular, the method of using geophysical anomalies to guide probe installation for targets that are known to have metal containers has proven to be effective in most cases. On the other hand, experience shows that the intensity of geophysical anomalies clearly is not correlated with contamination levels.

Newly identified study areas and logging results are consistent with logging results obtained from previous logging campaigns. The mixtures and amounts of radionuclides observed in the new study areas are within the same range as those previously observed, with a few exceptions. Exceptions include the detection of high cesium-cobalt levels in Area 2 and the identification of widespread Eu-154 in many new study areas. It is likely that Eu-154 also occurs in many previously logged SDA probeholes as well; its apparent absence is attributable to the circumstance that this radionuclide either was not targeted for analysis by the previous subcontractor or was missed because of gamma-ray interference with another radionuclide.

Two innovative data collection efforts yielded important results. In one effort, azimuthal data were measured at 6-in. depth intervals within several probes. These data clearly illustrated the heterogeneous character of radionuclide distribution, showing that both apparent concentration and position of radionuclide sources change continually with depth. In the second effort, long-count, high-sensitivity gamma-ray spectra were obtained within the soil zone underlying waste in two probes. These data showed that vertical migration of radionuclides into the underlying soil is not a vigorous process.

Logging data acquisition, data processing, and analysis methods have been refined so that the OU 7-13/14 program can now very quickly and efficiently explore the SDA subsurface to obtain useful qualitative information regarding the nature of waste-zone contamination in selected areas. Significant progress also has been made toward consolidating and archiving the extensive amounts of surface and probehole geophysics data that have been collected at the SDA over the last 10 years. These efforts will ensure that new data may be obtained and that old data will be available to address future issues that arise during remediation efforts.

Quantitative analysis of surface and probehole geophysics data continues to be a challenge. The uncertainty is almost always traceable to the highly heterogeneous character of the SDA waste seam. The most promising progress on quantitative methods has been related to chlorine distribution, perhaps because chlorine contamination seems to be much more widespread and spatially continuous than radionuclide contamination.

## 7.4 Conclusions

The combined use of WasteOScope inventory data and surface geophysics was generally successful for locating subsurface contamination within the SDA. In most cases, the contamination was consistent with the expected waste inventory.

Logging data within 37 new probes installed during FY 2003 show contamination mixtures and levels similar to previous SDA logging with the following exceptions:

- Very high cesium-cobalt levels were observed in Area 2
- Eu-154 was identified as a common constituent in many of the new study areas.

Measurement of azimuthal data at 6-inch depth intervals in two probes showed that both apparent concentration and position of radionuclide sources change continually with depth, supporting the conclusion that radionuclide contamination in the SDA is highly heterogeneous.

High-sensitivity measurements within underburden soil in two probes showed that downward vertical migration of radionuclides is very limited.

## **7.5 Recommendations**

Additional long-count measurements at selected locations should be considered as a means to directly evaluate the downward migration of radionuclides and VOCs into the vadose zone beneath the SDA waste pits and trenches.

The geophysical database compilation effort should be completed in order to ensure that these valuable data sets are available in the future.

Data acquisition and data analysis summaries should be formalized to document the FY 2003–2004 Type A logging activities in more detail.

Quantitative analysis methods for Type A logging data, particularly methods related to quantifying subsurface VOCs, should continue to be developed. The current development program promises to produce useful insight into the problems inherent to highly heterogeneous environments, which will likely apply to other quantitative issues.

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